299-W18-181 (A7663)
Log Data Report

Borehole Information:

Borehole:	299-W18-181 (A7663)		Site:	216-Z-12 Crib	
Coordinates (WA St Plane)		GWL[1] (ft):	None	GWL Date:	01/31/06
North (m)	East (m)	Drill Date	TOC Elevation	Total Depth (ft)	Type
135458.616	566363.844	05/80	687.61 ft	137	Cable tool

Casing Information:

Casing Type	Stickup (ft)	Outer Diameter (in.)	Inside Diameter (in.)	Thickness (in.)	Top (ft)	Bottom (ft)
Welded Steel	3.0	6 5/8	6	5/16	3.0	135

Borehole Notes:

The logging engineer measured the steel casing diameter and stickup using a steel tape.

The "Well Completion Report" indicates grout outside the 6-in. casing to 15 ft; log data indicate the grout extends to approximately 18 ft, consistent with adjustment for the 3 ft stickup. A grout plug was placed in the bottom of the borehole casing from 135 to 137 ft.

Log data acquisition is referenced to the top of casing.

Logging Equipment Information:

Logging System:	Gamma 4N	Type:	HPGe (60%) SN: 45-TP22010A
Effective Calibration Date:	08/16/05	Calibration Reference:	DOE-EM-GJ953-2005
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Logging System:	Gamma 4 F	Type:	NMLS SN: H380932510
Effective Calibration Date:	10/14/05	Calibration Reference:	DOE-EM-GJ1020-2005
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Logging System:	Gamma 4 I	Type:	PNLS SN: U1754
Effective Calibration Date:	N/A	Calibration Reference:	Not required
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Spectral Gamma Logging System (SGLS) Log Run Information:

Log Run	1	2	3	4 Repeat	
Date	01/31/06	02/01/06	02/01/06	02/02/06	
Logging Engineer	Spatz	Spatz	Spatz	Spatz	
Start Depth (ft)	136.5	62.5	38.5	30.5	
Finish Depth (ft)	61.5	3.5	29.5	18.5	
Count Time (sec)	100	100	400	400	
Live/Real	R	R	R	R	
Shield (Y/N)	N	N	N	N	

Log Run	1	2	3	4 Repeat	
MSA Interval (ft)	1.0	1.0	0.5	0.5	
ft/min	NA	NA	NA	NA	
Pre-Verification	DN201CAB	DN211CAB	DN211CAB	DN221CAB	
Start File	DN201000	DN211000	DN211060	DN221000	
Finish File	DN201075	DN211059	DN211078	DN221024	
Post-Verification	DN201CAA	DN211CAA	DN211CAA	DN222CAA	
Depth Return Error (in.)	- 1	- 1	0	0	
Comments	Fine gain adjustment after file -061.	No fine gain adjustment	No fine gain adjustment	No fine gain adjustment	

Neutron Moisture Logging System (NMLS) Log Run Information:

Log Run	8	9	10 Repeat		
Date	02/07/06	02/08/06	02/08/06		
Logging Engineer	Spatz	Spatz	Spatz		
Start Depth (ft)	50.5	136.5	50.25		
Finish Depth (ft)	3.0	50.5	36.0		
Count Time (sec)	N/A	N/A	N/A		
Live/Real	R	R	R		
Shield (Y/N)	N	N	N		
Sample Interval (ft)	0.25	0.25	0.25		
ft/min	1.0	1.0	1.0		
Pre-Verification	DF132CAB	DF142CAB	DF142CAB		
Start File	DF132000	DF142000	DF142345		
Finish File	DF132190	DF142344	DF142402		
Post-Verification	DF132CAA	DF142CAA	DF142CAA		
Depth Return Error (in.)	- 1	N/A	- 1		
Comments	None	None	None		

Passive Neutron Logging System (PNLS) Log Run Information:

Log Run	5	6 Repeat	7		
Date	02/02/06	02/03/06	02/03/06		
Logging Engineer	Spatz	Spatz	Spatz		
Start Depth (ft)	136.5	87.5	72.5		
Finish Depth (ft)	73.5	73.5	3.5		
Count Time (sec)	N/A	N/A	N/A		
Live/Real	R	R	R		
Shield (Y/N)	N	N	N		
Sample Interval (ft)	1.0	1.0	1.0		
ft/min	1.0	1.0	1.0		
Pre-Verification	DI312CAB	DI322CAB	DI322CAB		
Start File	DI312000	DI322000	DI322015		
Finish File	DI312063	DI322014	DI322084		
Post-Verification	DI312CAA	DI322CAA	DI322CAA		
Depth Return Error (in.)	- 1	N/A	0		
Comments	None	None	None		

Logging Operation Notes:

Logging was conducted with a centralizer on each sonde and measurements are referenced to top of casing. Repeat data were acquired at 400 second counting time at 0.5 ft intervals to provide additional detail of the highest activity zone. For purposes of this report, the data acquired at 400 seconds are reported as main log data rather than as repeat data.

Analysis Notes:

Analyst:	P.D. Henwood	Date:	06/07/07	Reference:	GJO-HGLP 1.6.3, Rev. 0

Pre-run and post-run verifications for the logging systems were performed before and after the day's data acquisition. The acceptance criteria were met.

A casing correction for a 5/16 in. thick was applied to the SGLS data.

SGLS spectra were processed in batch mode using APTEC SUPERVISOR to identify individual energy peaks and determine count rates. Concentrations were calculated with an EXCEL worksheet template identified as G4NAug05.xls using an efficiency function and corrections for casing, dead time, and water as determined from annual calibrations. The NMLS data were converted from count rate to percent volumetric moisture according to calibration for a 6-in. ID borehole. The passive neutron data are used for qualitative purposes and do not require a calibration. Data are reported in counts per second.

Results and Interpretations:

Am-241 is detected almost continuously from 21 to 37 ft. There appears to be three distinct depth intervals of contamination above the MDL: 21.5 to 25.5 ft, 27 to 30 ft, and 32 to 34.5 ft. The maximum concentration is measured at approximately 1,100,000 pCi/g at 23 ft. Gamma rays at approximately 662, 722, and 208 keV were detected that represent Am-241. Cs-137 emits a 661.66 keV gamma ray that cannot be distinguished from the 662.40 keV gamma ray emitted from Am-241. The energy peak at 722.01 keV is used to establish the presence of Am-241 rather than Cs-137. In this borehole, the 722.01 keV energy peak is used to determine the Am-241 concentration. When comparing the assays for Am-241 using the 662 and 722 keV energy peaks, there appears to be residual counts in the 662 keV energy peak that may be attributed to Cs-137. On the basis of the 722.01 keV assay, counts from the 662 keV energy peak were subtracted which yields an approximate contribution from Cs-137.

Using this approach, Cs-137 is detected between 21 and 35 ft. The maximum concentration of 143 pCi/g is measured at approximately 22 ft.

The Am-241 concentrations derived from the 208.01 keV gamma line are significantly over estimated. A 208.000 keV gamma line that results from the decay of U-237 (daughter of Pu-241), interferes with the 208.01 keV gamma line caused by the decay of Am-241. For purposes of this report, it is assumed that all of the counts in the 208 keV energy peak that cannot be attributed to Am-241, reflect decay of U-237. Assuming the waste stream is aged (e.g., 40 years or more), U-237 has grown into equilibrium with its parent Pu-241. After subtracting the influence of Am-241 (based on the 722.01 energy peak) from the 208 keV energy peak, it is estimated Pu-241 exists between 22 and 35 ft at a maximum concentration of approximately 5,000,000 pCi/g; the maximum concentration is at 23 ft in depth.

Pu-239 was detected from 21 to 38 ft. As identified with the Am-241 profile, three distinct depth intervals of contamination appear to exist. The maximum concentration was measured at 23 ft at approximately 4,235,000 pCi/g. Primary energy peaks associated with Pu-239 were detected at approximately 345, 375, and 414 keV. Interferences from the 375.45 and 376.65 keV energy lines and the 415.76 and 415.88 keV gamma energy lines originating from the decay of Pa-233 and Am-241, respectively, are probable and would result in a slight over estimation of the Pu-239 concentration. However, assays compared with the 345.01 keV energy peak (which has no obvious interferences) are consistent. Therefore, it is concluded the interferences are minor and the assay using the 413.71 keV energy peak is the most reasonable. The yields of the 413.71 and 375.05 keV gamma rays are similar (0.0015 and 0.0016 percent, respectively) and an order of magnitude greater than the 345.01 keV yield (0.0006 percent). The 375.05 keV gamma line has more potential interferences than the 413.71 keV gamma line.

Weapons grade plutonium is generally defined as approximately 6 % by weight of ^{240}Pu. The table below relates a hypothetical weapons grade Pu mix of the dominant isotopes by weight to activity.

Isotope (Weapons grade)	^{239}Pu	^{240}Pu	^{241}Pu
Half life (years)	24,110	6,563	14.35
Weight (percent)	93.8	5.8	0.13
Activity (percent)	27.07	6.12	62.50

Even though Pu-239 is more abundant on a weight basis, Pu-241 has a much higher specific activity. The approximate 2:1 (62.5/27.07) activity ratio of Pu-241/Pu-239 is not consistent with the ratio measured in this borehole (5,000,000/4,000,000). This result could indicate that the Pu has aged sufficiently since created so that the Pu-241 is decaying away.

Although Pu-240 was not detected with the SGLS due to a lack of emission of relatively high yielding gamma rays, it almost certainly exists in this waste stream. Using the assumptions in the table above, the Pu-239/Pu-240 activity ratio is approximately 4:1 that would suggest a Pu-240 concentration of approximately 1,000,000 pCi/g.

Np-237 is detected with the SGLS by measuring a daughter product (protactinium-233 that emits a prominent gamma ray at an energy of 312.17 keV. Pa-233 was detected from 21 to 36.5. The maximum concentration is approximately 105 pCi/g at a 22 ft depth.

An elevated Th-232 concentration as determined using the 2615 keV (Tl-208) energy peak is indicated between 21 and 26.5 ft. Both U-232 and Th-232 decay to Th-228, the first decay product of U-232 and the third decay product of Th-232. Therefore, the concentration determined for each decay product from Th-228 to Tl-208 will reflect decay from both parents. In spectral gamma log analysis, the 2615 keV Tl-208 gamma ray is used to represent the concentration of the naturally occurring parent Th-232. This gamma ray is energetic relative to gammas emitted by the other daughter products and its yield of approximately 35% results in easy detection. However, because the decay chain of naturally occurring Th-232 is modified by the emergence of the decay products of U-232, the natural component of Th-232 must be determined from its second decay product (Ac-228). Ac-228 can be directly measured using the 911 keV gamma ray. The plot of natural gamma logs shows the disruption of the equilibrium (i.e., separation of the 911 and 2615 keV assays) of the natural Th-232 decay, where between 21 and 26.5 ft, the Ac-228 indicates Th-232 concentrations below that calculated from the 2615 keV gamma line.

To determine the concentration of U-232, the activity due to natural decay of Th-232, must be subtracted. The Ac-228 concentration is subtracted from the Th-232 concentration calculated based on the 2615 keV Tl-208 energy peak. The result is a maximum concentration of approximately 1.8 pCi/g U-232.

U-233 almost certainly exists where U-232 is detected. In a reactor using thorium target material, U-233 will be generated at roughly three orders of magnitude more than U-232. However, at relatively low concentrations, U-233 does not emit a gamma ray that can be detected with the SGLS and decay products that potentially could be measured have not had sufficient time to build in to detectable levels. It is inferred on the basis of the U-232 concentration that 100 to 1000 pCi/g U-233 may exist in this waste stream.

Passive neutron logging was performed in the borehole. This logging method has been shown to be effective in qualitatively detecting zones of alpha-emitting contaminants from secondary neutron flux generated by the (α,n) reaction and may indicate the presence of α-emitting nuclides, including transuranic radionuclides, even where no gamma emissions are available for detection above the MDL. The passive neutron signal depends on the concentration of α sources, and also the concentrations of lighter elements such as N, O, F, Mg, Al, and Si, which emit neutrons after alpha capture. The passive neutron log indicated a maximum count rate of 545 counts per second (cps) at 23.5 ft.

A reaction F-19 (α,n) Na-22 yields a gamma ray at 1274.53 keV and a positron (annihilation peak) at 511 keV. A 1274.44 keV gamma ray also occurs from the decay of Eu-154. However, there are no corroborating peaks for the Eu-154 and the gamma ray is attributed to the fluorine reaction. The half-life of Na-22 is short (i.e., 2.6 years), but will continue to be produced as long as sufficient fluorine and alpha activity exist. The Na-22 was detected from 21 to 34 ft at similar depth intervals as the relatively high Pu-239 and Am-241. The maximum concentration of Na-22 is approximately 6 pCi/g at 23.5 ft. The 1274 keV energy peak may also be influenced by a prompt gamma ray induced by alpha particles interacting with F-19. Other energy peaks observed in the spectra that could be attributed to reactions with F-19 include ones at approximately 196, 583, 890, and 1236 keV. The existence of these gamma rays strongly suggests that at least some of the alpha emitting radionuclides are present as a fluoride.

Other energy peaks are observed in the high neutron flux intervals that represent capture gamma rays from elements in the formation, steel casing, or the waste stream itself. Gamma rays detected and possible sources include a 2223.2-keV H capture γ-ray, Al-22(n,g) at 1779 keV or Mg-25 (α,n) at 1779 keV, and Mn-56 at 846.75 keV and 1810.72 keV.

Spectral gamma data were acquired in this borehole in 1993 and 1998 by Westinghouse Hanford Company and Waste Management Federal Services NW, respectively, using the Radionuclide Logging System (RLS). A comparison plot of the RLS (1993 and 1998) and SGLS (2006) manmade radionuclides show similar concentrations for Pa-233 and Pu-239. However, Am-241 concentrations are significantly different. It is suspected the RLS analysis utilized a different energy peak (such as the 60 keV energy peak) to determine Am-241 concentrations rather than the current analysis which uses the 722.01 keV energy peak. The low energy peak at 60 keV is out of the SGLS calibration range, as it is severely attenuated by the steel casing. Additionally, some increase in Am-241 concentrations should be expected as a result of the decay of the parent Pu-241.

The RLS analysis identified a "thorium disequilibrium" condition. Current analysis suggests this disequilibrium is an indication of U-232.

The RLS analysis appears to have attributed all of the counts in the 662 keV peak to Cs-137. The current analysis has identified approximately 6 of a total 361 counts in the highest 662 energy peak to be from Am-241. Consequently, subtracting the Am-241 influence from the 662 keV peak, only causes the Cs-137 assay to be approximately 2 pCi/g less. The comparison of the Cs-137 profiles from 1993 to 2006 suggests no significant change. However, the Cs-137 concentrations should have decreased by 15 to 20 percent due to decay. The apparent lack of decay suggests the 662 keV energy peak may have contributions from other radionuclides. It is also postulated that small amounts of fission products may be produced in situ by fissioning of Pu-239 in the intense neutron flux.

Soil samples were acquired and analyzed for Pu-239/240 and Am-241 at the time of drilling the borehole in 1980. Kasper (1982) reports the detection limits for Pu-239/240 and Am-241 using gamma energy analysis were 2,000 and 300 pCi/g, respectively. The detection limits using the SGLS are approximately 10,000 and 30,000 pCi/g. For soil samples below the GEA detection limits, alpha energy analysis was performed. The detection limit for Pu-239/240 and Am-241 alpha energy analysis was approximately 0.1 pCi/g. These sample results plotted with the SGLS/RLS results indicate good agreement except for the sample at approximately 31.5 ft. It is believed this sample, as well as those at approximately 26 ft, were acquired in a sediment layer that did not adsorb significant contamination. The profiles of the SGLS data also suggest lower concentrations at these depths. The design of the crib was such that the bottom of the distribution pipe (20 ft) lies on top of a 3 ft thick gravel layer. It is postulated the contaminants readily passed through the gravel and adsorbed to a sediment layer below the extent of the gravel at approximately 23 ft. Further downward deposition was controlled by thin sediment layers of differing grain size.

Moisture data indicate some variability although grout is reported to be in the annular space outside the 6- in. casing from 0 to 18 ft. A comparison of the 2006 moisture data with soil sample moisture data (loss on drying) acquired in 1980 (Kasper, 1982), generally indicates consistent results. One exception is the finer grained sediments below approximately 130 ft, where it appears these sediments contained more moisture in 1980 than is currently indicated. The moisture log data from approximately 22 to 24 ft is influenced by the neutron flux from the (α,n) reactions and probably does not represent higher moisture content.

The SGLS, NMLS, and PNLS repeat logs all show good repeatability.

References:

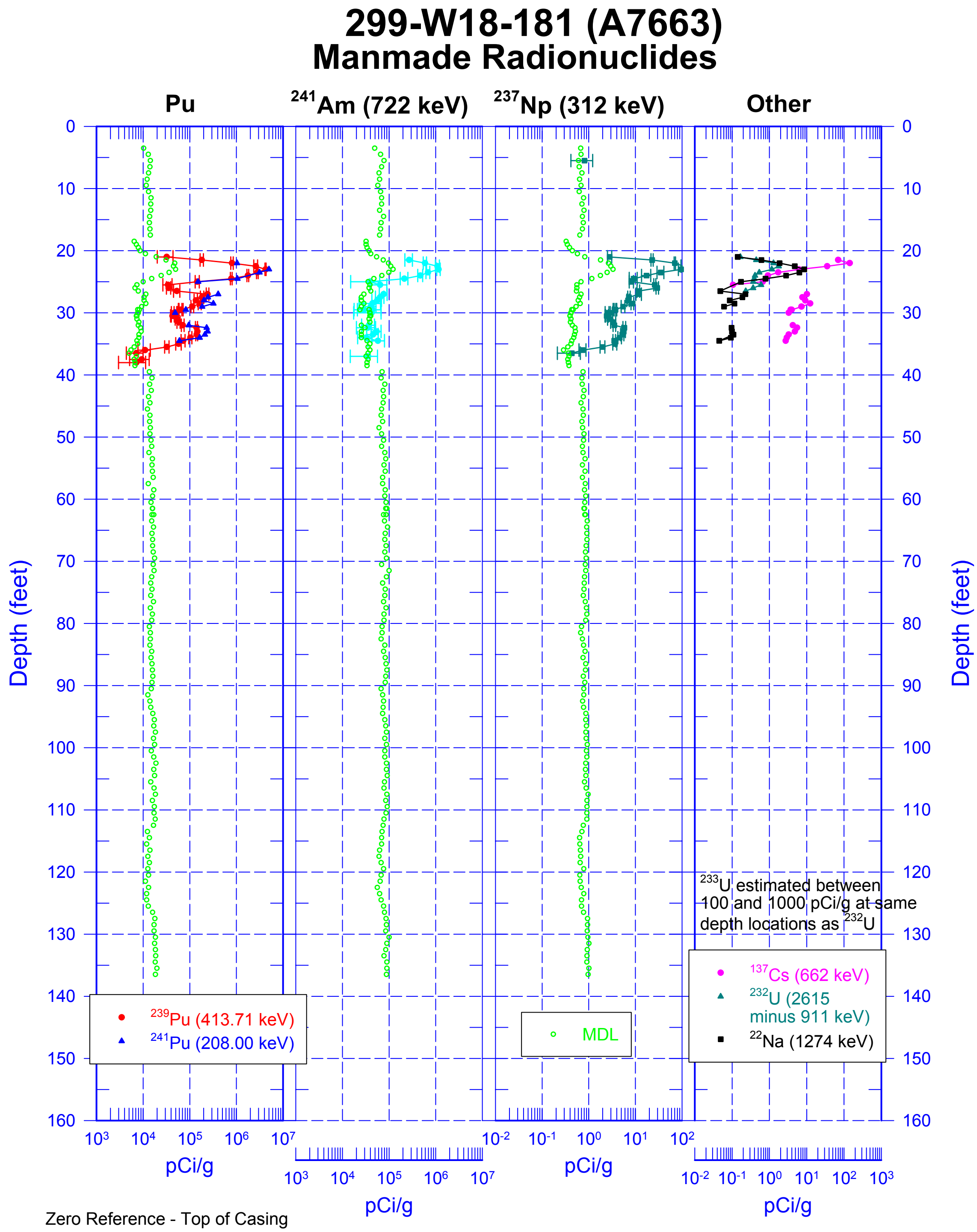
1982. Kasper, R.B. *216-Z-12 Transuranic Crib Characterization: Operational History and Distribution of Plutonium and Americium*. RHO-ST-44. Rockwell Hanford Operations. Richland, Washington.

List of Log Plots:

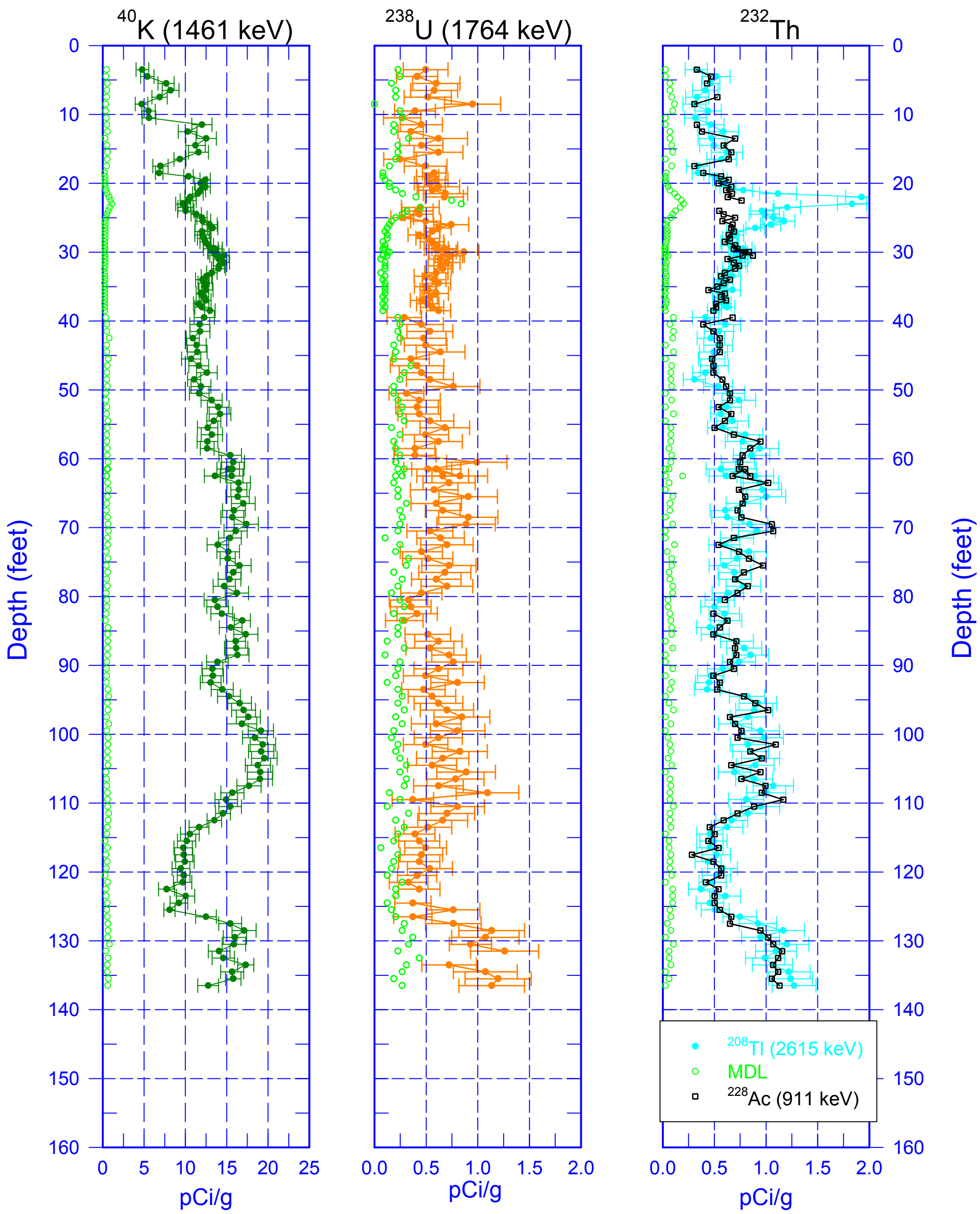
Depth Reference is top of casing

Manmade Radionuclides
Natural Gamma Logs
Combination Plot
Total Gamma, Dead Time, Moisture, & Passive Neutron
Comparison of RLS/SGLS & Soil Samples (0-40 ft)
Comparison of RLS/SGLS & Soil Samples (0-160 ft)
Repeat of Selected Manmade Radionuclides
Repeat of Natural Gamma Logs
Repeat of Total Gamma, Moisture, & Passive Neutron

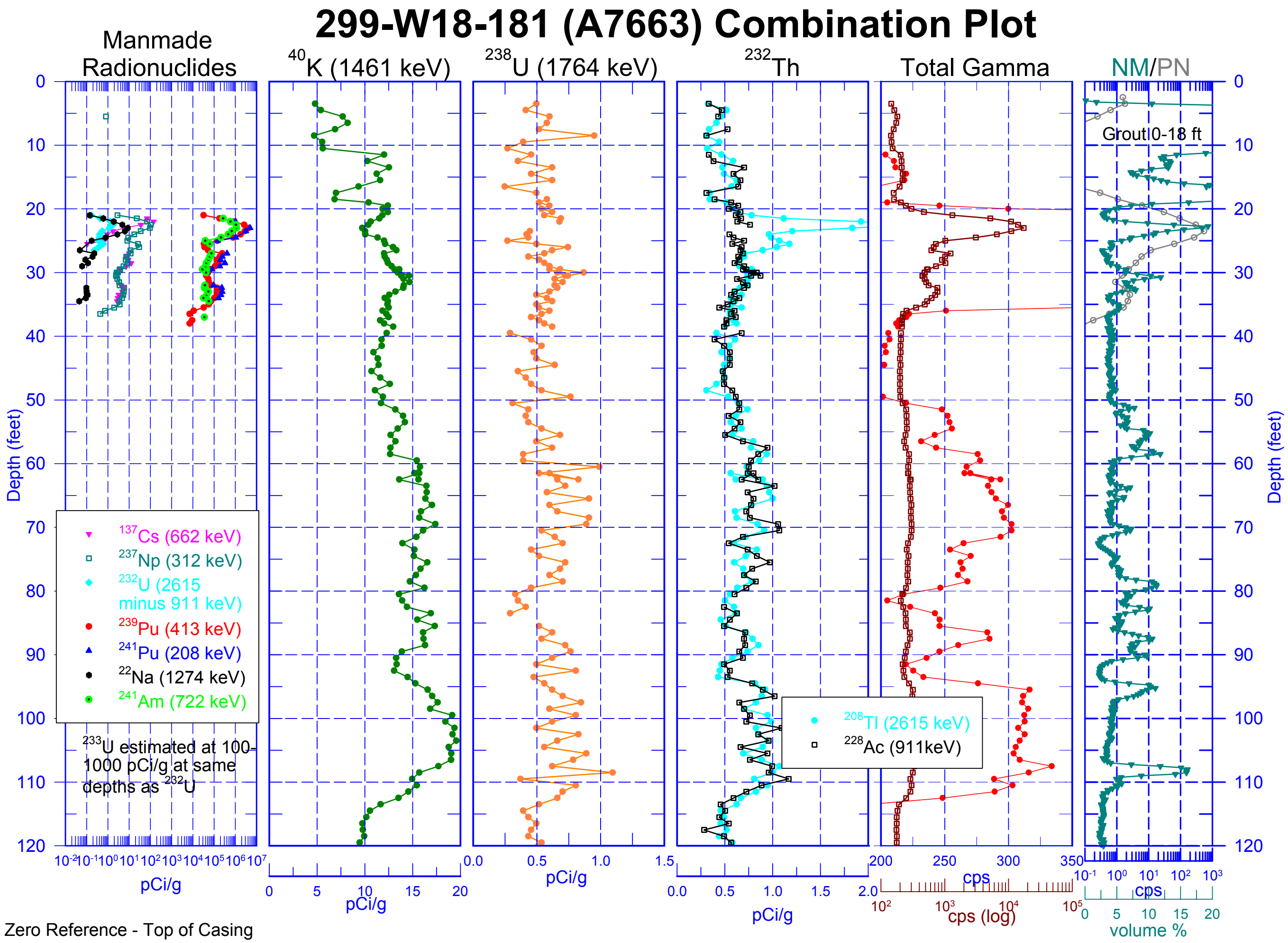
[1] GWL – groundwater level


299-W18-181 (A7663)
Manmade Radionuclides
Pu
241Am (722 keV)
237Np (312 keV)
Other
Depth (feet)
239Pu (413.71 keV)
241Pu (208.00 keV)
MDL
233U estimated between 100 and 1000 pCi/g at same depth locations as 232U
137Cs (662 keV)
232U (2615 minus 911 keV)
22Na (1274 keV)
pCi/g
Zero Reference - Top of Casing

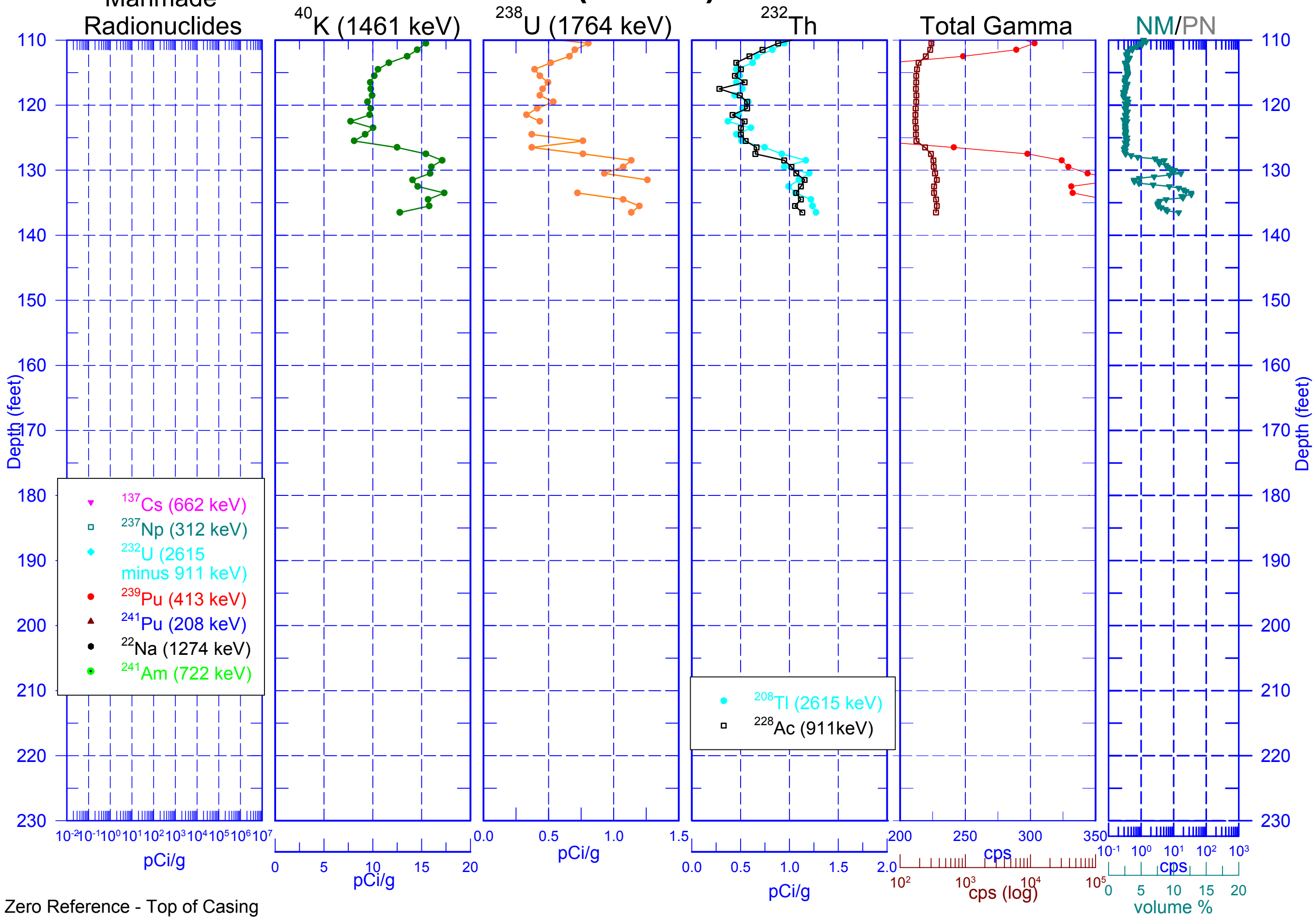
299-W18-181 (A7663)
Natural Gamma Logs



Zero Reference = Top of Casing

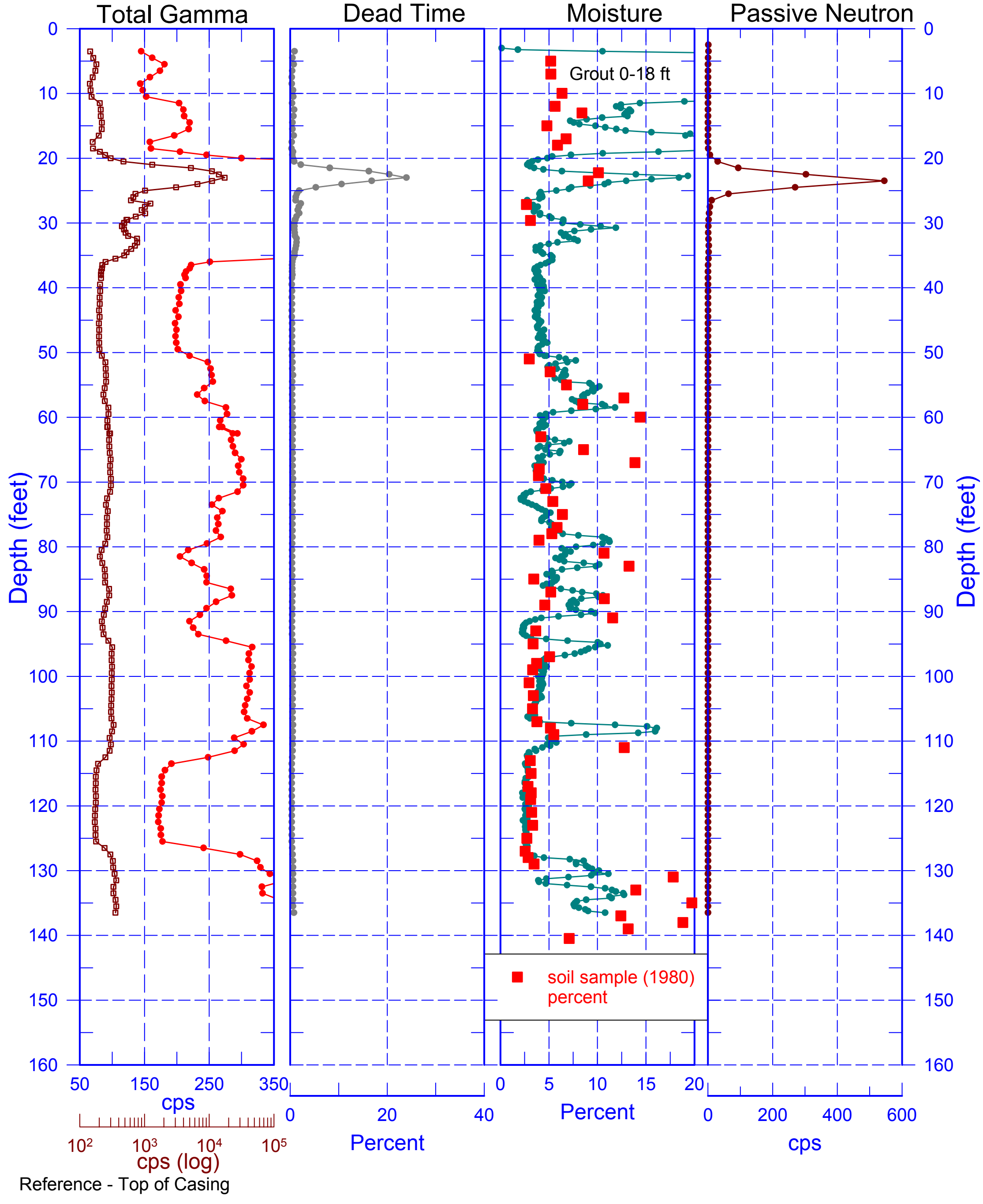

299-W18-181 (A7663) Combination Plot
Manmade Radionuclides
40K (1461 keV)
238U (1764 keV)
232Th
Total Gamma
NM/PN
Depth (feet)
Grout 0-18 ft
137Cs (662 keV)
237Np (312 keV)
232U (2615 minus 911 keV)
239Pu (413 keV)
241Pu (208 keV)
22Na (1274 keV)
241Am (722 keV)
233U estimated at 100-1000 pCi/g at same depths as 232U
208Tl (2615 keV)
228Ac (911keV)
pCi/g
cps
cps (log)
volume %
Zero Reference - Top of Casing

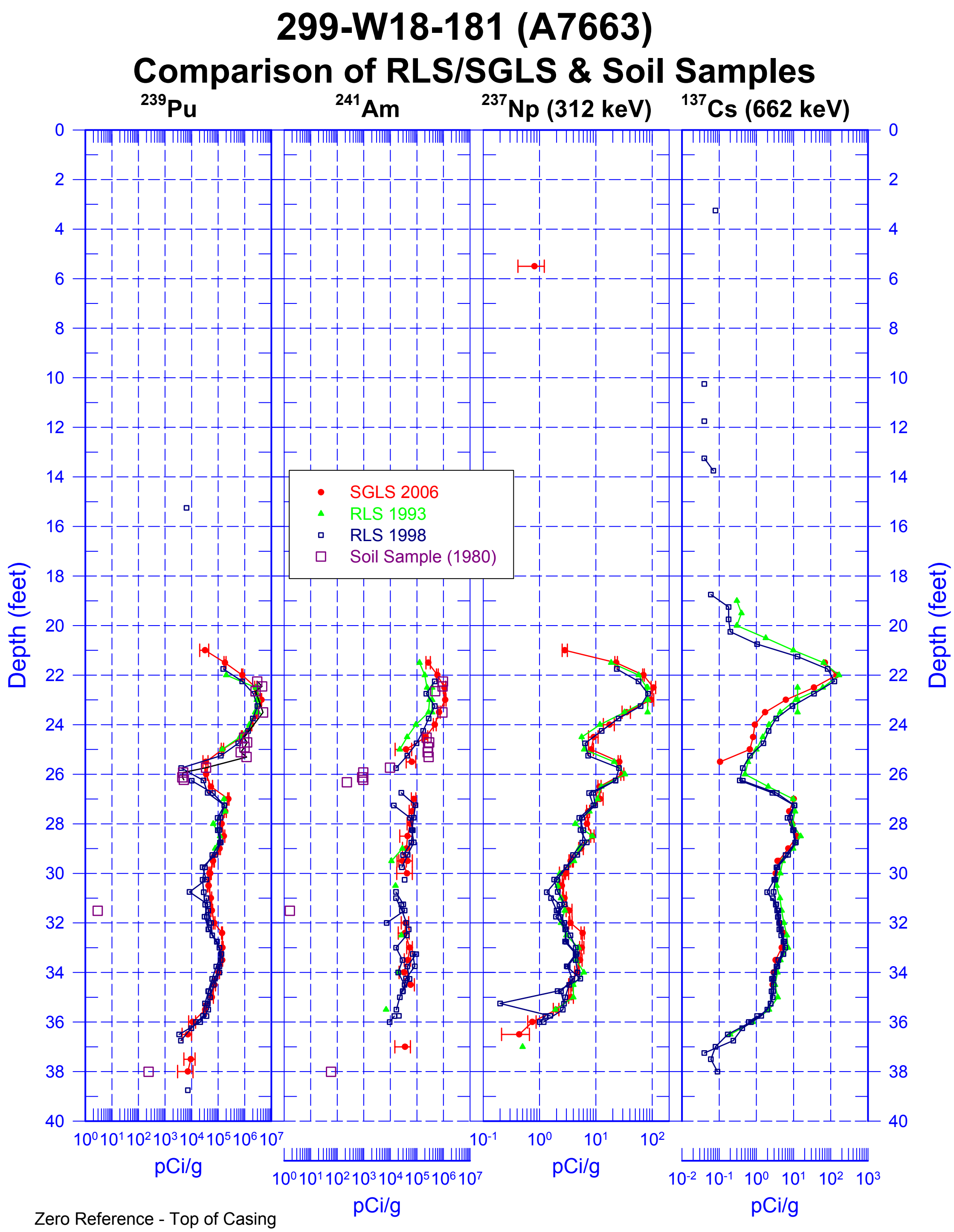
299-W18-181 (A7663) Combination Plot

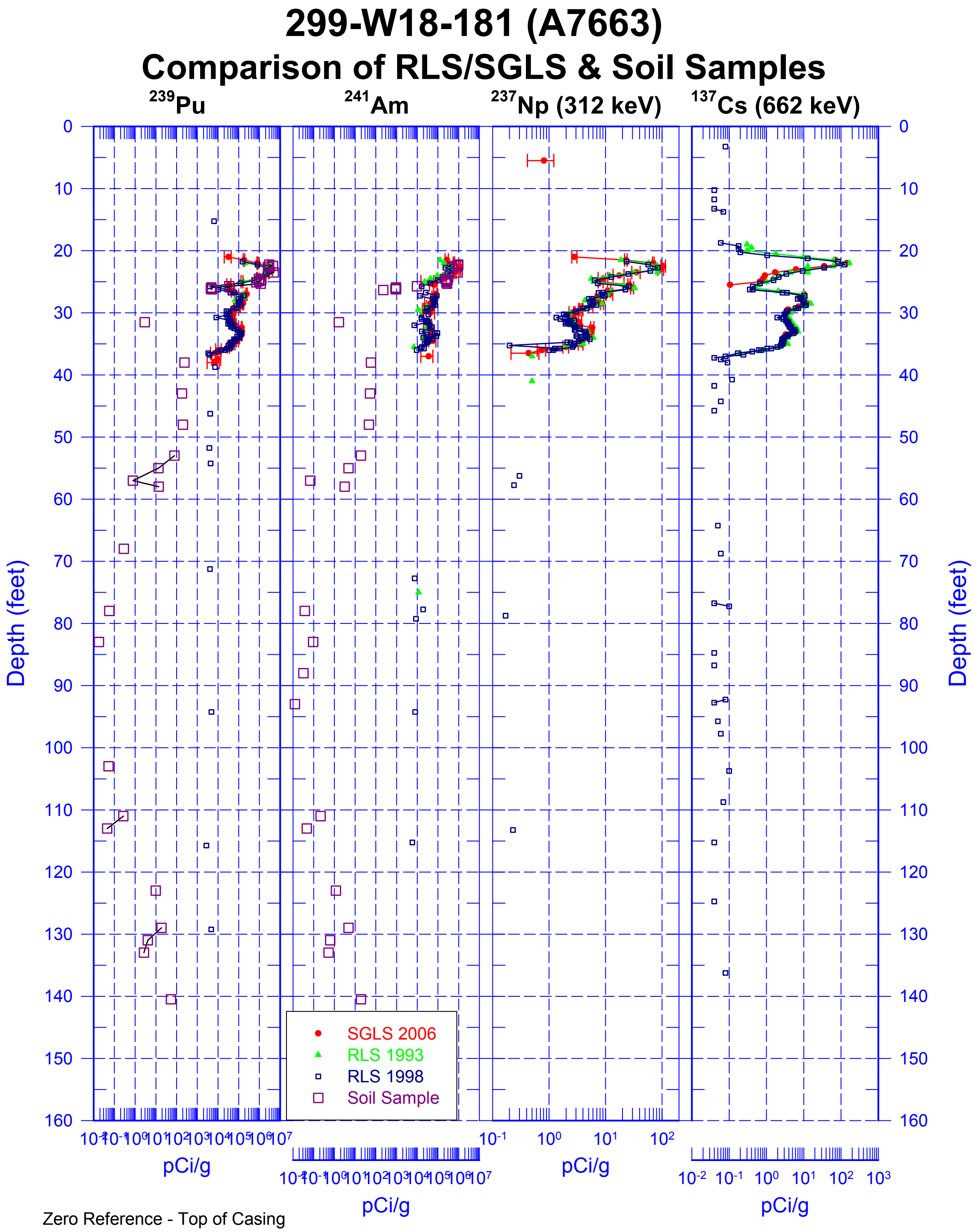


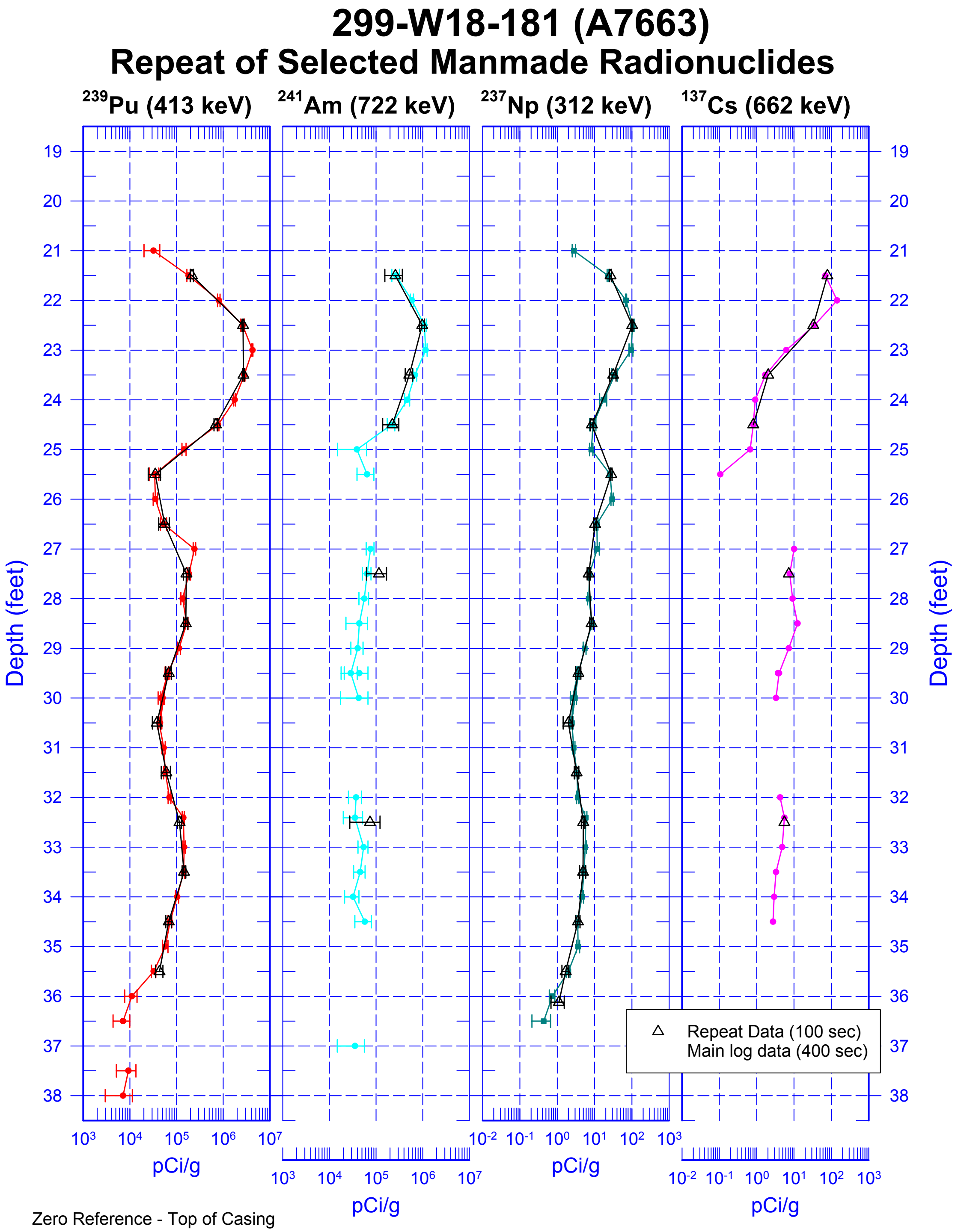
Zero Reference - Top of Casing

299-W18-181 (A7663)
Total Gamma, Dead Time, Moisture, & Passive Neutron

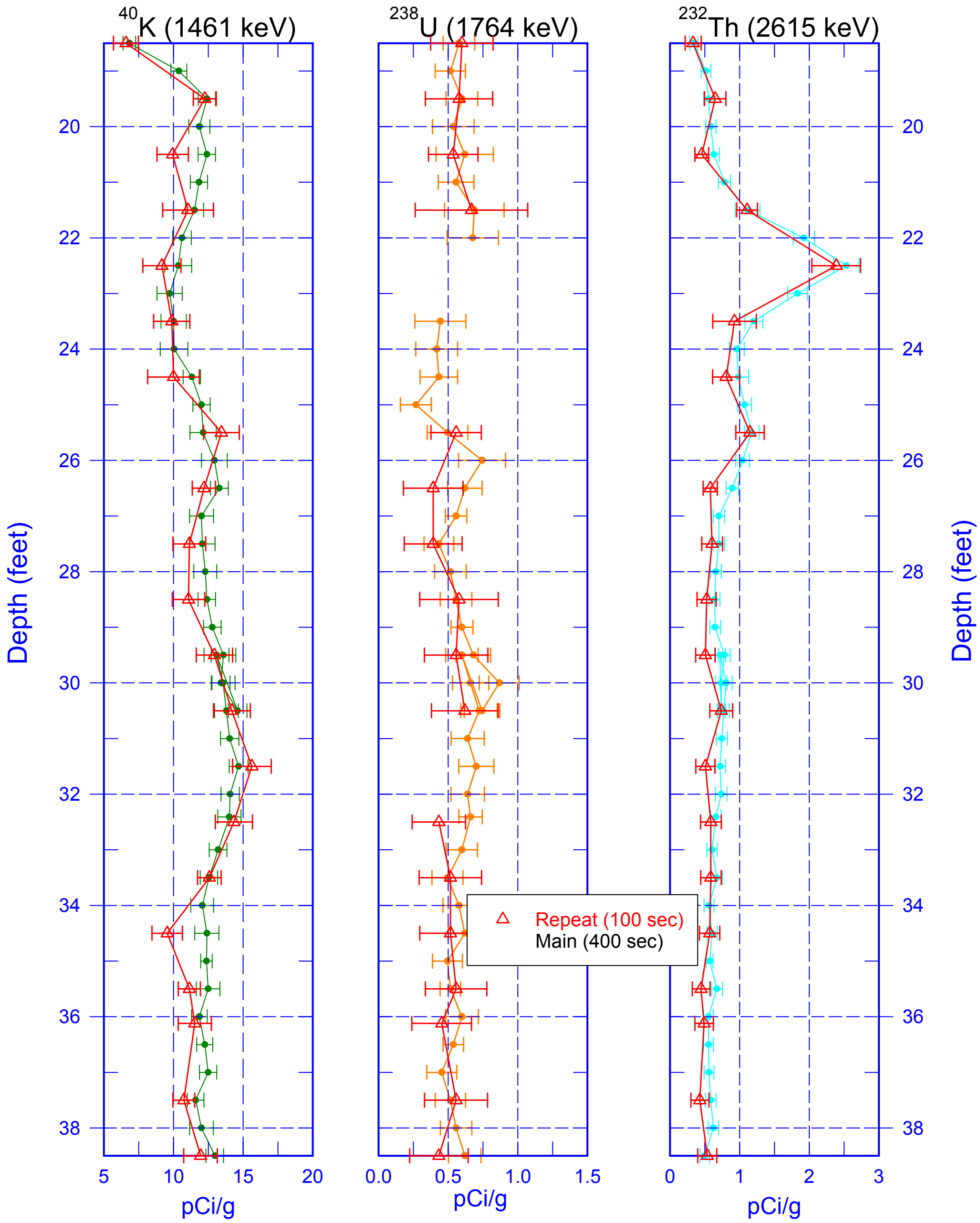



299-W18-181 (A7663)
Comparison of RLS/SGLS & Soil Samples
239Pu
241Am
237Np (312 keV)
137Cs (662 keV)
SGLS 2006
RLS 1993
RLS 1998
Soil Sample (1980)
Depth (feet)
pCi/g
Zero Reference - Top of Casing


299-W18-181 (A7663)
Comparison of RLS/SGLS & Soil Samples
239Pu
241Am
237Np (312 keV)
137Cs (662 keV)
Depth (feet)
pCi/g
SGLS 2006
RLS 1993
RLS 1998
Soil Sample
Zero Reference - Top of Casing

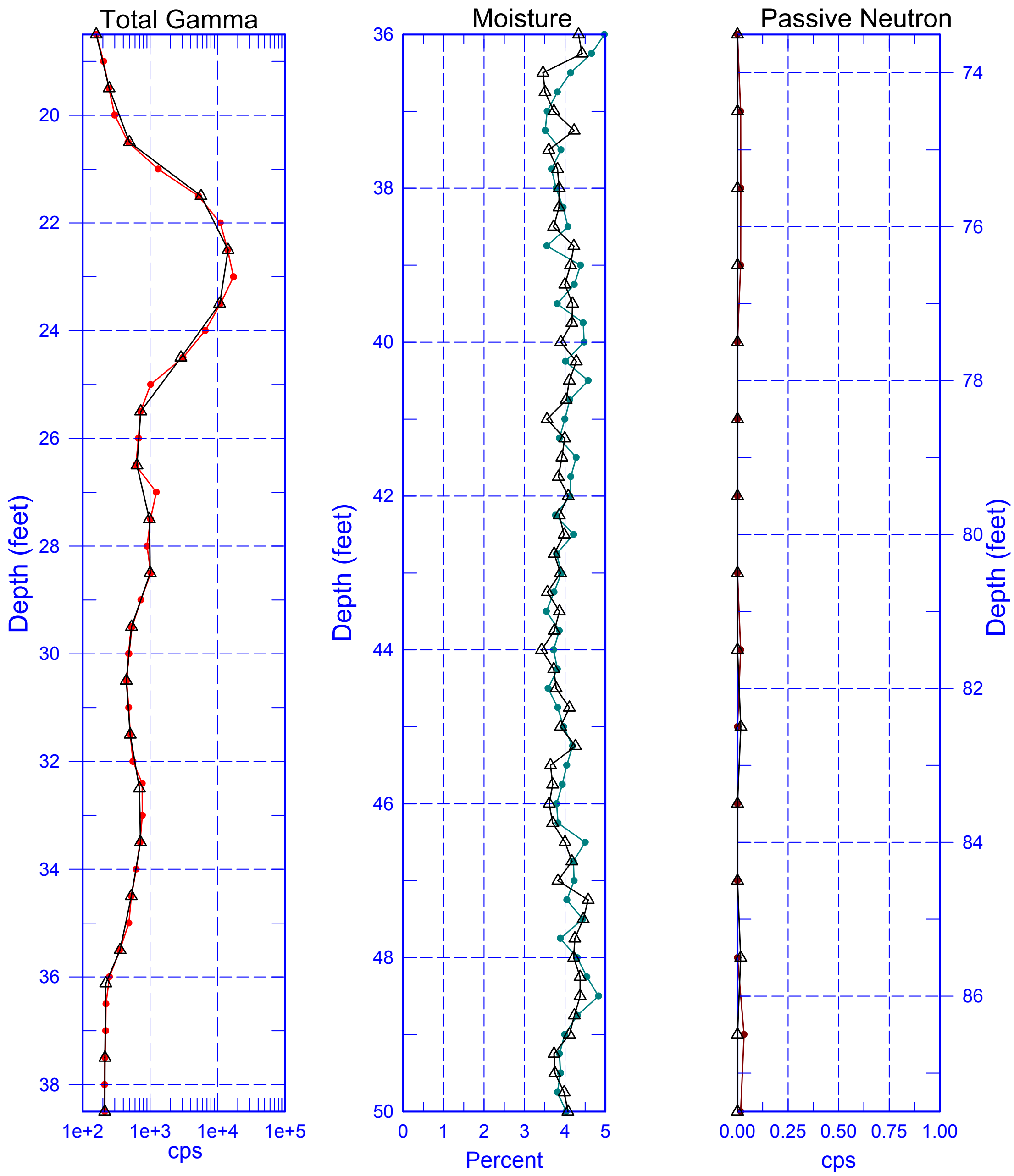

299-W18-181 (A7663)
Repeat of Selected Manmade Radionuclides
239Pu (413 keV)
241Am (722 keV)
237Np (312 keV)
137Cs (662 keV)
Depth (feet)
pCi/g
Repeat Data (100 sec)
Main log data (400 sec)
Zero Reference - Top of Casing

299-W18-181 (A7663)
Repeat of Natural Gamma Logs



Zero Reference = Top of Casing

299-W18-181 (A7663)
Repeat of Total Gamma, Moisture, & Passive Neutron



Reference - Top of Casing